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GEOLOGICAL SURVEY

Geology and mineral resource potential of the Pigeon Canyon (AZ-010-109), Nevershine Mesa (AZ-010-105A), and Snap Point (AZ-010-105B) Wilderness Study Areas, Mohave County, Arizona

By

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Open-File Report 83-888
1983

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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STUDIES RELATED TO WILDERNESS

Bureau of Land Management Wilderness Study Areas

The Federal Land Policy and Management Act (Public Law 94-579, October 21, 1976) requires the U.S. Geological Survey and the U.S. Bureau of Mines to conduct mineral surveys on certain areas to determine their mineral resource potential. Results must be made available to the public and be submitted to the President and the Congress. This report summarizes the results of mineral survey of the Pigeon Canyon (AZ-010-109), Nevershine Mesa (AZ-101-105A), and Snap Point (AZ-010-105B) Wilderness Study Areas, Mohave County, Arizona, as designated by the U.S. Bureau of Land Management.

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SUMMARY

The Pigeon Canyon, Nevershine Mesa, and Snap Point Wilderness Study Areas (WSAs) are located at the transition between the Colorado Plateau (to the east) and Basin and Range Province (to the west). The Colorado Plateau part is underlain by well exposed and little-faulted Paleozoic rocks ranging from the Cambrian Muav Limestone to the Permian Kaibab Formation. The Basin and Range part, in the Grand Wash trough, is underlain by conglomerate, sandstone, siltstone, gypsum, and limestone of the Miocene Muddy Creek Formation, which is mostly unfaulted and which covers tilted Paleozic and possibly Mesozoic rocks at an unknown depth. The Grand Wash fault, a large displacement, high-angle normal fault that trends north, separates the two parts but is not exposed in the area.

The Pennsylvanian-Permian Pakoon and Callville Limestones host collapse structures, some of which are mineralized in and near the WSAs or in the Grand Canyon region; these have yielded substantial quantities of copper, uranium, and other metals. The Pigeon Canyon WSA has four such localized areas with moderate resource potential for copper, uranium, and other metals in untested collapse structures; a part of the mineralized Savanic Mine collapse structure also lies within the WSA. The Nevershine Mesa WSA has a copper-bearing deposit at the Cunningham Mine collapse structure, which lies partly within the WSA. A small area between the Savanic and Cunningham Mines has a moderate mineral resource potential for copper, uranium, and other metals because of the proximity of the two mineralized collapse structures and associated joints that may be mineralized. The remainder of both the Pigeon Canyon and the Nevershine Mesa WSAs has a low mineral resource potential for metals, as the likelihood of the occurrence of other collapse structures is low. The Snap Point WSA has no known mineralized zones or collapse structures.

Nonmetallic mineral resources (building stone, sand and gravel, gypsum, and limestone) are abundant in the WSAs, but all these materials are readily available outside the wilderness study areas and are more accessible to markets in Utah and Nevada. The resource potential for oil and gas is moderate in the parts of the Pigeon Canyon and Nevershine Mesa WSAs west of the Grand Wash fault, where the Paleozoic rocks are buried; east of the Grand Wash fault the Paleozoic rocks are exposed, and the potential is low in all three WSAs. No coal-bearing rocks were observed in the WSAs and none are expected to be found in the subsurface. No other indications of mineral resource potential were found.

INTRODUCTION

This report describes and summarizes three Wilderness Study Areas (WSAs) located in Mohave County, northwest Arizona (fig. 1). From 1981 to 1983 the U.S. Geological Survey and the U.S. Bureau of Mines jointly conducted field investigations to evaluate the mineral potential of the Pigeon Canyon, Nevershine Mesa, and Snap Point Wilderness Study Areas. Field studies by the U.S. Geological Survey included geologic mapping by Ivo Lucchitta, L. S. Beard, and H. J. Rieck, geochemical sampling by J. C. Antweiler, and a reconnaissance survey for undiscovered collapse structures by G. H. Billingsley. M. E. Lane, U.S. Bureau of Mines, examined known mines, prospects, and mineralized areas in and near the WSAs and mapped and sampled all mine workings. In addition, the Bureau of Mines conducted a search of courthouse and Bureau of Land Management records for information on mining claim locations and oil and gas leases.

Acknowledgments

The Bureau of Mines appreciates information provided by the 5M Mining Corporation, Hurricane, Utah, concerning the Savanic and Grand Gulch Mines and information on collapse structures provided by Energy Fuels Exploration Company, Denver, Colorado.

Geographic setting

The study areas, Pigeon Canyon, Nevershine Mesa, and Snap Point, measure 33,348, 19,457, and 9,500 acres respectively, for a total of 62,305 acres. This terrain is in the Arizona Strip, that part of Arizona north of the Colorado River, among the most remote and inaccessible parts of the state. The nearest town of any consequence is St. George, Utah, about 50 airline miles north of the study area. Access from the south is blocked by the Grand Canyon and Lake Mead. Most of the area can be reached with some difficulty from the north by means of the moderate-duty Wolf Hole-Shivwits Plateau dirt road, then by the small and rough Pigeon Canyon dirt road (see geologic map--plate 1). The distance from St. George is about 90 miles along these roads, which may become impassable in wet weather. The westernmost part of the area is accessible via the partly paved St. Thomas Gap road from Mesquite, Nevada, thence by jeep trails in the Grand Wash country. The area straddles the boundary between the Colorado Plateau and the Basin and Range Province. This boundary is defined here by the Grand Wash fault system, whose fault-line scarp trends approximately north, and is expressed by two large steps down to the west--the Upper and the Lower Grand Wash Cliffs. The terrain above the upper step is on the Shivwits Plateau, the westernmost of the plateaus that collectively form the Colorado Plateaus Province. Altitudes here typically range from 6,000 to 6,500 ft, attaining a maximum of 6,710 ft at Snap Point. The terrain below and west of the lower step is part of the Grand Wash trough, within the Basin and Range Province. Altitudes in this part of the area range from 2,000 to 3,000 ft. Between the two steps is a bench, also part of the Colorado Plateau, at an altitude of 4,400 to 4,600 ft. Whereas the steps consist of precipitous cliffs passable with difficulty in only a few places, the bench terrain adjoining the steps is relatively flat and easily passable.

Mining activity

Since 1873, copper and associated silver and lead have been mined intermittently in the vicinity of the Wilderness Study Areas. Mining and prospecting have occurred at four localities. Two short adits and a trench at one locality in upper Snap Canyon (fig. 2) are within the Snap Point WSA and part of the Cunningham Mine is in the Nevershine Mesa WSA; part of the Savanic Mine is in the Pigeon Canyon WSA; the other localities are outside the WSAs. The Grand Gulch (fig. 2) is within 1/4 mile of the Pigeon Canyon WSA.

As of April 1983, there was no mining activity in the three wilderness study areas, but two mining companies (the 5M Mining Corporation and Uranez) were planning jointly to drill near the Savanic and Cunningham Mines near the Nevershine Mesa WSA to investigate possible uranium resources.

Several companies have located large groups of claims in and near the WSAs. Many oil and gas leases also are in and near the areas. There are no patented claims within the WSAs; however, there is one patented claim just outside the Pigeon Canyon WSA at the Grand Gulch Mine.

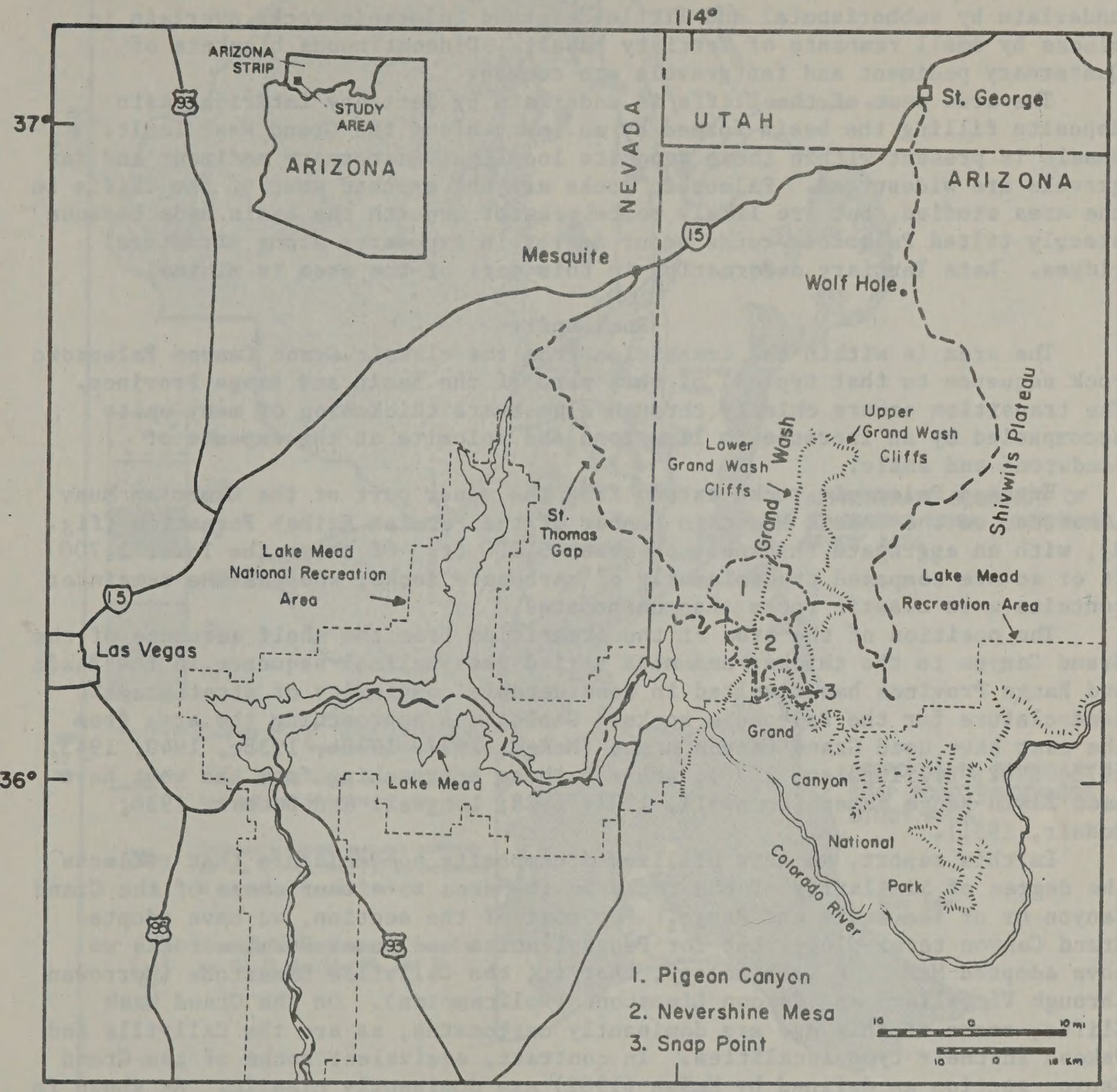


Figure 1.--Index map showing the location of the Pigeon Canyon (AZ-010-109) (1), Nevershine Mesa (AZ-010-105A) (2), and Snap Point (AZ-010-105B) (3) Wilderness Study Areas, Mohave County, Arizona.

GEOLOGY

The part of the area east of and including the Lower Grand Wash Cliffs is underlain by subhorizontal and little-deformed Paleozoic rocks overlain in places by small remnants of Tertiary basalt. Discontinuous blankets of Quaternary pediment and fan gravels are common.

The area west of the Cliffs is underlain by Tertiary interior-basin deposits filling the basin formed by movement along the Grand Wash fault. Basalt is present within these deposits locally. Quaternary pediment and fan gravels are widespread. Paleozoic rocks are not exposed west of the Cliffs in the area studied, but are likely to be present beneath the basin beds because steeply tilted Paleozoic rocks occur nearby in exposures along structural ridges. Late Tertiary deformation in this part of the area is minimal.

Rock units

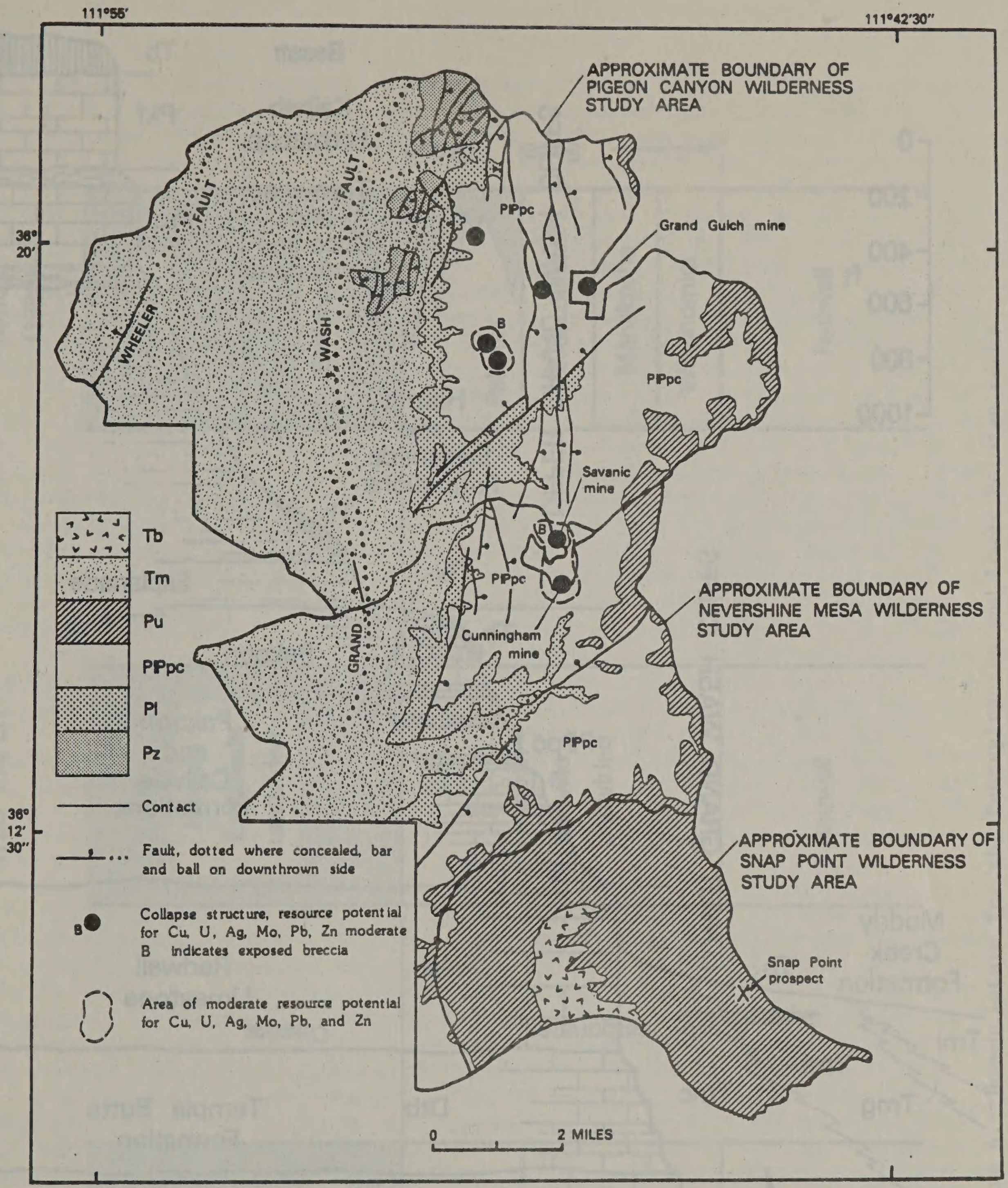
The area is within the transition from the classic Grand Canyon Paleozoic rock sequence to that typical of this part of the Basin and Range Province. The transition occurs chiefly through a westward thickening of many units accompanied by an increase in limestone and dolomite at the expense of sandstone and shale.

Exposed Paleozoic rocks extend from the upper part of the Cambrian Muav Limestone to the Fossil Mountain Member of the Permian Kaibab Formation (fig. 3), with an aggregate thickness of about 5,000 ft. Of these the lower 2,700 ft or so are composed predominantly of carbonate rocks, whereas the remainder contains more clastic rocks than carbonates.

The position of the area at the transition from the shelf sequence of the Grand Canyon to the thicker and more varied geosynclinal sequence in the Basin and Range Province has resulted in considerable complexity of stratigraphic nomenclature for the Paleozoic rocks. Geologists approaching the area from the east have used Grand Canyon names (McKee, 1937, 1938b, 1938c, 1940, 1945, 1975, 1982; Billingsley, 1978), whereas those approaching from the west have used Basin-Range names (Longwell, 1921, 1928; Longwell and Dunbar, 1936; McNair, 1951).

In this report, we have utilized a composite nomenclature that reflects the degree of similarity of the rocks in the area to either those of the Grand Canyon or of the Basin and Range. For most of the section, we have adopted Grand Canyon terminology, but for Pennsylvanian and lower Permian rocks we have adopted McNair's terminology, that is, the Callville Limestone (Morrowan through Virgilian) and Pakoon Limestone (Wolfcampian). On the Grand Wash Cliffs, rocks of this age are dominantly carbonates, as are the Callville and Pakoon in their type localities. In contrast, equivalent rocks of the Grand Canyon section as defined by McKee (1982) are dominantly clastic. As shown in figure 4, the Grand Canyon equivalents of the Callville Limestone are the Watahomigi, Manakacha, and Wescogame Formations of the Supai Group, whereas the Pakoon Limestone is equivalent to part of the Esplanade Sandstone, which is the uppermost formation of the Supai Group.

The break between the carbonates of the Callville and Pakoon and the clastics of the Esplanade and Hermit is a distinctive and conspicuous mappable contact. In contrast, the breaks within the carbonate and clastic sequences are much less visible. Accordingly, the Callville and Pakoon have been combined in this study, as have the Esplanade and Hermit.


111°55′
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36° 20′
36° 12′ 30″
APPROXIMATE BOUNDARY OF PIGEON CANYON WILDERNESS STUDY AREA
Grand Gulch mine
WHEELER FAULT
GRAND WASH FAULT
PIPpc
B
Savanic mine
Cunningham mine
APPROXIMATE BOUNDARY OF NEVERSHINE MESA WILDERNESS STUDY AREA
APPROXIMATE BOUNDARY OF SNAP POINT WILDERNESS STUDY AREA
Snap Point prospect
Tb
Tm
Pu
PIPpc
Pl
Pz
Contact
Fault, dotted where concealed, bar and ball on downthrown side
Collapse structure, resource potential for Cu, U, Ag, Mo, Pb, Zn moderate
B indicates exposed breccia
Area of moderate resource potential for Cu, U, Ag, Mo, Pb, and Zn
0
2 MILES

Figure 2.--Simplified geologic map showing areas of moderate or high mineral resource potential in the Pigeon Canyon, Nevershine Mesa, and Snap Point WSAs. Tb: basalt; Tm: Muddy Creek Formation; Pu: Kaibab Formation (Fossil Mountain Member), Toroweap Formation, Coconino Sandstone, Hermit Shale, Esplanade Sandstone; PIPpc: Pakoon and Callville Limestones (host to collapse structures); Pl: Redwall Limestone, Temple Butte Formation, Muav Limestone; Pz: Paleozoic rocks, undifferentiated. High resource potential areas are at the Savanic and Cunningham Mines.

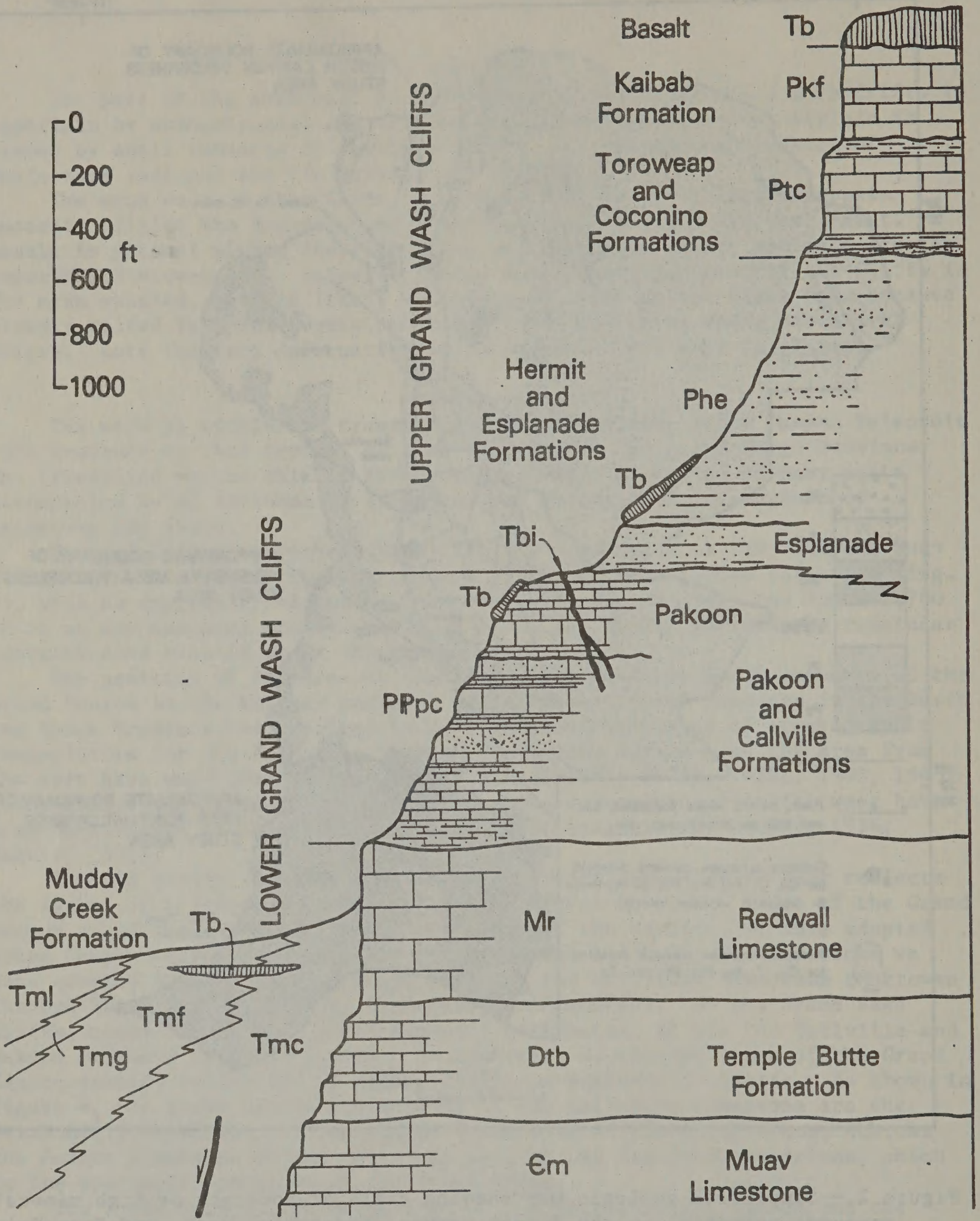

Figure 3.--Generalized stratigraphic section of the Paleozoic rocks at the Grand Wash Cliffs, Mohave County, Arizona. Tertiary rocks include olivine basalt, Tb, a basaltic dike, Tbi, and the Muddy Creek Formation, comprised of a conglomeratic facies, Tmc, a sandstone-siltstone-mudstone facies, Tmf, a gypsum facies, Tmg, and a limestone facies, Tml.

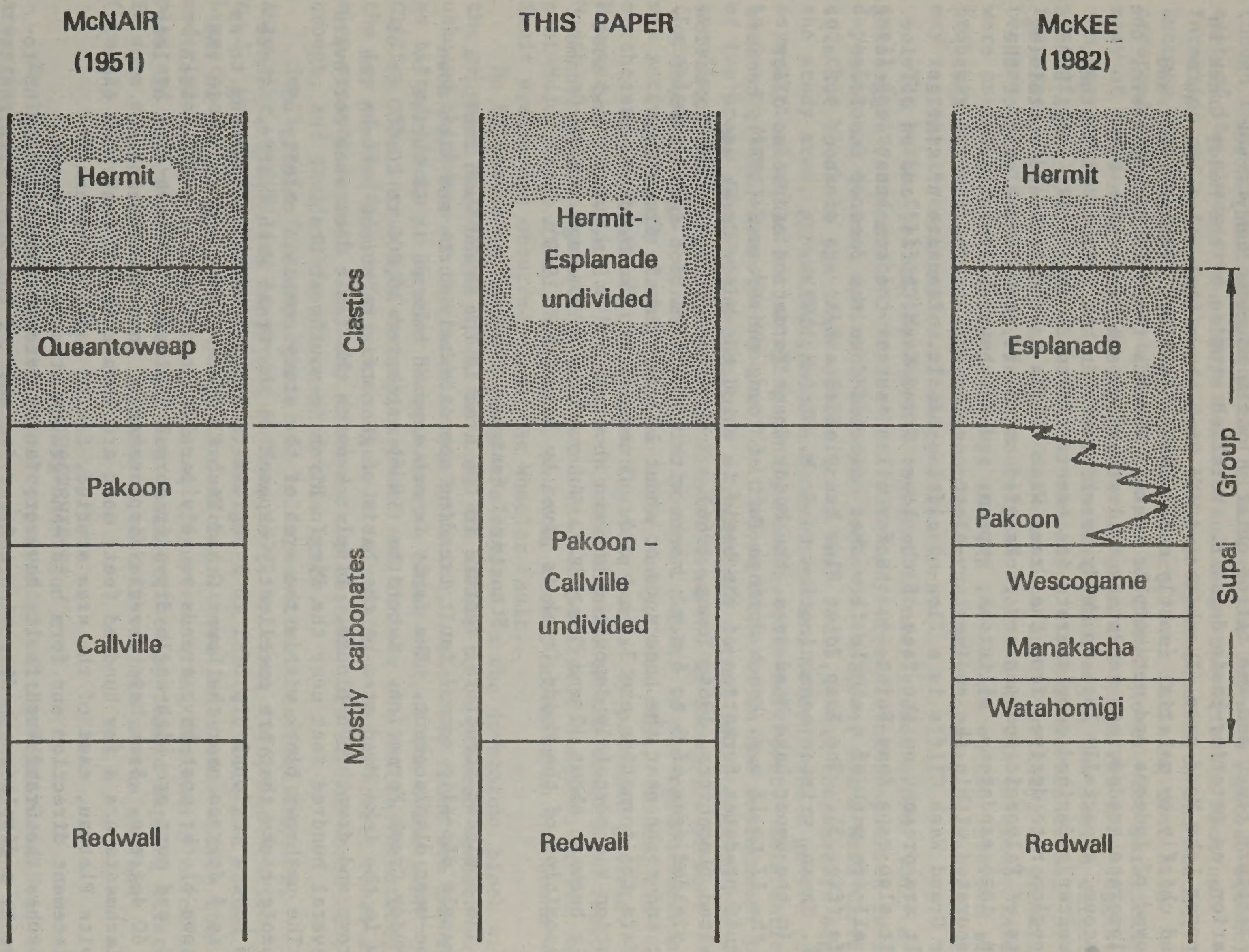

Figure 4.--Nomenclature for the Pennsylvanian and Lower Permian rocks in the western Grand Canyon and eastern Great Basin areas.

Cenozoic rocks occur mostly in the Grand Wash trough west of the Grand Wash Cliffs. The trough was formed by movement on the Grand Wash fault in late Tertiary time, and was filled chiefly by the Miocene Muddy Creek Formation, an interior-basin deposit. Detailed studies of the Muddy Creek in the upper Lake Mead area (Lucchitta, 1966) have shown that the basin was filled chiefly by material (mostly conglomerate) derived from the west and composed of igneous and metamorphic rocks. Towards the axis of the basin, the conglomerate graded into sandstone, siltstone, gypsum, and fresh-water limestone, especially late in Muddy Creek time. In the area of this study, the westerly-derived conglomerate is absent. Instead, relatively small bodies of conglomerate derived from the Grand Wash Cliffs to the east and containing clasts of Paleozoic sedimentary rocks grade westward, toward the axis of the basin, into sandstone, siltstone, gypsum, and fresh-water limestone. Incorporated within the sedimentary-clast conglomerate at the foot of the Lower Grand Wash Cliffs is a flow of olivine basalt. Remnants of similar basalt are present on the face of the lower Grand Wash Cliffs, and an olivine basalt also caps Snap Point, just a few miles east of the remnants, suggesting that all are part of a single flow that cascaded down the face of the lower Cliffs (fig. 3). The Snap Point flow has yielded a K/Ar age of about 9.2 m.y. (J. F. Haman, written communication to G. E. Ulrich, 1983).

In the upper Lake Mead area, the Muddy Creek Formation can be no older than the 17 to 18 m.y. Peach Springs Tuff of Young and Brennan (1974), because the tuff predates formation of the basin in which the Muddy Creek was deposited (Lucchitta, 1966; Young, 1966). Rocks near the top of the formation have yielded ages of 5 to 6 m.y.; rocks within the formation ages of about 8 m.y.; and rocks near the base ages of about 11 m.y. Basalt flows that postdate the formation are 3.8 m.y old. Consequently, the Muddy Creek Formation was certainly deposited between about 17 and 3.8 m.y.b.p., and most likely between about 12 and 5 m.y.b.p. An overview of the age and environment of deposition of the Muddy Creek is given by Lucchitta (1979).

Structural features

The dominant structural feature in the area is the Grand Wash fault, a high-angle dip-slip normal fault trending approximately north and with down-to-the-west displacement. The fault is not exposed because it is buried by the Muddy Creek Formation. Lucchitta (1966) estimated 10,000 to 20,000 ft of throw in the Lake Mead area on the basis of geometric relations between the upthrown and downthrown blocks. Displacement on the fault decreases northward to several hundred feet near the Virgin River in southwest Utah.

The upthrown block within the area of the study consists chiefly of Paleozoic rocks that are excellently exposed in the Grand Wash Cliffs. These rocks have a regional dip of 1 to 2 degrees to the northeast, steepening to as much as 5 degrees near the Lower Grand Wash Cliffs. Faults are common in the upthrown block; most have trends roughly parallel to that of the Grand Wash fault, and most are high-angle dip-slip normal faults, a few have dips of less than 60 degrees. Some have reverse displacement. In a few instances, displacements are a few hundred feet; most are less than 100 feet. On the Shivwits Plateau, east of the area studied, faults have no systematic displacement direction and form horst-and-graben structures. As one approaches the Grand Wash fault, however, faults become systematically up-to-the-west, a displacement direction contrary to that of the Grand Wash fault.

Most of the faults on the upthrown blocks can be dated unequivocally only as post-Paleozoic because they cut only Paleozoic rocks. A more refined though indirect age assignment can be made on the Shivwits Plateau directly east of the study area, where similar faults cut the Triassic Moenkopi Formation and a few faults cut late Miocene lavas (Lucchitta and Jeanne, 1975; Huntoon, Billingsley, and Clark, 1982). Hence, most faulting must have occurred between Triassic time and the end of the Miocene. The parallelism of many of the faults to those in the nearby Basin and Range Province suggests a similar age for both: mid- to late-Miocene. However, a few faults directly east of the lower Grand Wash Cliffs pass along strike into monoclinal flexures. A "Laramide" age (Late Cretaceous to early Tertiary) is probable, because that is when many of the monoclinal flexures of the Colorado Plateau were presumably formed. In summary, some of the faults on the upthrown block probably are of Laramide age; most are mid- to late-Miocene, and some of these may represent reactivation of older structures.

The basin fill on the downthrown block is nearly undeformed. Only a few small faults and gentle warps affect the Muddy Creek Formation, which is in depositional contact against Paleozoic rocks of the lower Grand Wash Cliffs and thus blankets the trace of the Grand Wash fault. Near the western edge of the study area, gypsum beds of the Muddy Creek are folded into a gentle asymmetrical anticline plunging gently to the north-northeast. This anticline is due to drag along the Wheeler fault whose trace is in the westernmost part of the area. The Wheeler fault is a high-angle normal fault down to the west, trending northeast, and with displacement measured in thousands of feet (Lucchitta, 1966). It is one of the youngest faults in the region because it was active not only during but also after Muddy Creek time. Toward the northeast, the trace of the Wheeler fault is buried by pediment gravels. However, a projection of the exposed trace intersects the Grand Wash fault. North of this intersection, the Grand Wash Fault itself has been active in post-Muddy Creek time. Evidently, the most recent movement on the Grand Wash fault system has occurred along the Wheeler fault.

No Paleozoic or Mesozoic rocks are exposed in the downthrown block within the proposed wilderness area, but they are likely to be present beneath an unknown thickness of the Muddy Creek Formation. Paleozoic rocks are exposed as tilted blocks in Wheeler Ridge, about 4 miles west of the Grand Wash Cliffs. The strata dip steeply eastward and include the Kaibab Formation, at the top of the Paleozoic rocks. Thus it is possible that Mesozoic rocks are also present beneath the Muddy Creek in the eastern part of the Grand Wash trough, and thus within the area of this study.

Small scale features consist of collapse structures (Billingsley, Antweiler, and Ellis, in press; Hoffman,1977; Watkins, 1976; and Wenrich, K. J., written communication) that are hosted in the Callville and Pakoon Limestones and that resulted from solution in these limestones and in the underlying Redwall Limestone. The collapse structures, dominantly circular in plan and bell-shaped in section, are characterized by inward dipping strata. In some collapse structures, brecciated rock is visible at the surface (breccia pipes).

GEOCHEMISTRY

Evaluation of the mineral resource potential of the Wilderness Study Areas is partly based on geochemical samples. In and near the Pigeon Canyon WSA, the average sampling density was one sample per 0.56 sq mi based on 93 samples (56 fine-grained stream-sediment samples (minus -80 mesh), 18 panned-concentrate samples, 18 rock samples, and one water sample). The average sampling density for the Nevershine Mesa WSA was one sample per 1.15 sq mi based on 30 samples of 17 fine-grained stream sediment samples, 5 panned concentrate samples, and 8 rock samples. In the Snap Point WSA, the average sampling density was one sample per 0.39 sq mi based on 38 samples of 25 fine-grained sediment samples, 5 panned-concentrate samples, 6 rock samples and 2 water samples. Collectively for the three WSAs, the average sampling density was one sample per 0.63 sq mi. Fine-grained stream-sediment samples were collected mainly from first-order (unbranched) streams. Negligible quantities of heavy minerals are in most drainages because the abundance of heavy minerals in the sedimentary source rocks is very low; therefore, panned concentrates were collected mainly below the confluence of two or more first-order streams. In order to determine the geochemical nature of mineralization, a number of samples were collected in the vicinity of the Grand Gulch, Cunningham, and Savanic mines.

All the samples except the water samples were analyzed by a six-step semiquantitative emission spectrographic procedure for 31 elements. Selected samples were analyzed by wet chemical methods for Au, Cu, Pb, U, Zn, and for Th and U by delayed-neutron activation procedures. The water samples were analyzed for Cu, Pb, Zn, U, sulfate, fluoride, chloride, pH, and conductivity. The geochemical data and pertinent geological parameters were stored on magnetic disk in the U.S. Geological Survey's computer in Denver, Colorado. Geochemical data applicable to evaluation of mineral resource potential are discussed here. Details of collection, preparation, and analyses of samples are presented by Hopkins and others (1984).

Determination of thresholds above which concentrations of elements are considered anomalous was based on study data sets for each sample type (J. C. Antweiler, unpublished data, 1983). Most thresholds were based on concentration contrasts of elements in samples collected in the vicinity of the mines compared to those from non-mineralized areas. Samples from around the mines showed considerable enrichment in Ag, As, Cu, Mo, Pb, Sb, U and Zn: some of them were also somewhat enriched in Ba, Co, Ni, or Sr. In a few of the data sets, thresholds for Cu, Pb, Zn (determined chemically), U, Ba, Co, Ni, and Sr were suggested in plots of cumulative frequency versus element concentrations where the mineralized population was distinguished from the background population by a break in slope. In other data sets, thresholds for those same elements could not be recognized by that method, and were arbitrarily chosen to maximize recognition of possible anomalies. Analytical values at or above the detection limit were considered anomalous for Ag, As, Au, Mo, Sb, and Zn (determined spectrographically). Analytical values on the two water samples were rated as non-anomalous when compared with analytical data from 15 other water samples from the region.

Copper and silver were the metals of most interest in collapse-structure-type ores of the Grand Gulch, Savanic, and Cunningham Mines when they were developed in the latter half of the 19th century. In recent years, uranium has been discovered in similar collapse structures at a number of places in the Grand Canyon region. Samples from the three mines near the study areas contained as much as 0.07 percent U in some of the highly-mineralized rock samples. Therefore, other collapse features in the study areas were sampled with uranium specifically in mind, but no anomalies were found for U or for any other element. Special attention was given in the geochemical sampling survey to possibilities for uranium occurrences, not only in field traverses using scintillometers, but also in laboratory analyses employing delayed-neutron activation techniques and fluorometry methods. However, the only uranium anomalies were in samples taken around the mines.

No geochemical anomalies related to mineralization other than that associated with the three mines were found in the study areas. Several geochemical anomalies were apparent in fine-grained stream-sediment and panned-concentrate samples taken in drainages below the mines, but these anomalies could be related to mining activity. In Grand Gulch Canyon, north of the Grand Gulch Mine, fine-grained stream-sediment and panned-concentrate samples were anomalous in Cu, Pb, and other metals. However, these anomalies were traced to ore spills along a primitive wagon road through Grand Gulch Canyon that was formerly used for transporting ore from the Grand Gulch Mine to Kingman, Arizona.

Samples of gypsum from the Tertiary Muddy Creek Formation near the western boundary of the Pigeon Canyon WSA contained as much as 5,000 ppm Sr, 10 ppm Mo, and 50 ppm Sn. Although such concentrations makes them geochemically anomalous, the anomalies are directly relatable to the sedimentary deposits of gypsum, and are not of themselves indicative of mineral deposits in this environment.

MINING DISTRICTS AND MINERALIZED AREAS

During the field investigation 221 samples were taken from mine workings. Samples were analyzed for gold and silver by fire assay and for uranium by fluorometric methods. In addition, some samples were analyzed for certain elements by atomic absorption and for 42 elements by semiquantative spectrographic methods. Complete analyses are available for public inspection at the U.S. Bureau of Mines, Intermountain Field Operations Center, Denver Federal Center, Denver, Colorado 80225.

The Wilderness Study Areas are located in the old Bentley Mining District. Mining in and near the WSAs has been limited to three mineralized areas and excavation at one non-mineralized area. The three mineralized areas outside the WSAs are located on collapse structures (breccia pipes) that have been mined for copper. One prospect in the Snap Point WSA has no known minerals and is thought to have been an exploration pit mainly for water in a nearby seep spring (Cox and Russell, 1973) (fig. 2).

Many collapse structures throughout northern Arizona and the Arizona Strip are known to contain uranium and copper mineralization. Many of the collapse structures in the region contain brecciated rock fragments that in most instances are well-cemented by a fine-grained sandy matrix of siliceous or slightly calcareous composition. Low-temperature hypogene solutions possibly produced the primary mineralization of pyrite, chalcocite, and uraninite. Secondary enrichment of metals into medium- to high-grade ore was the result of supergene enrichment.

Savanic Mine

On April 20, 1878, James R. Cunningham located the Bronze L Mine (Savanic Mine) about three miles south of the Grand Gulch Mine. On June 13, 1880, the mine was acquired by George H. Dodge, C. W. Dodge, and A. R. Whitehead and became known as the Savanic. In 1906, the Savanic became controlled by Levi Syphus and Harry Gentry (Billingsley, in press). Elsing and Heineman (1936, p. 96) credit the Savanic with $300,000 production from 1906 to 1919, all in copper. There is no record of recent production.

The Savanic Mine is partly in the Pigeon Canyon WSA, in the SW 1/4 of section 9, T. 33 N., R. 14 W., about 400 feet below the rim of an unnamed side canyon of Pigeon Canyon and within 1/4 mile of the Nevershine Mesa WSA (plate 1 and fig. 2). The mine has two main levels connected to the surface by two shafts, one inclined, the other vertical. In addition, several pits and a short adit are at the surface. The main mine consists of extensive drifts, raises and stopes.

The breccia pipe associated with the mine is well concealed in the slope above the Savanic. Copper mineralization, which includes azurite, malachite, chalcopyrite, bornite, and chalcocite, is very spotty and occurs as disseminated stains, fillings in solution cavities, and fracture fillings forming an ore-mineral matrix to the breccia. Hematite is frequently associated with the copper minerals, especially in larger cavities wholly or partially filled by these minerals.

At present, the Savanic Mine has the highest-grade and most extensive copper mineralization remaining in any of the breccia pipes investigated near the WSAs, largely because much of the high-grade ore at the Grand Gulch Mine probably has been mined out. The highest copper value in samples taken from the Savanic Mine was 18 percent in a 14-inch chip sample and the highest uranium content was 19 parts per million (ppm) in a 18-inch chip sample (Lane, in press).

Cunningham Mine

The Cunningham Mine is located on a collapse structure partially in the Nevershine Mesa WSA and about 3/4 mile south of the Savanic in the NW 1/4 of section 16, T. 33 N., R. 14 W. (plate 1 and fig. 2). Inward-dipping strata of the collapse structure cover a large circular area 600 to 800 feet in diameter.

Brecciated rock is exposed in two adits. The rest of the workings consists of pits or trenches in which no structural boundaries are exposed. One adit shows a brecciated zone in dolomite and sandstone of the Pakoon Limestone, but this zone was not found in the adjacent adit.

Production figures from the Cunningham Mine are unknown. Copper mineralization occurs as malachite crusts and specks.

In the 30 samples taken at the Cunningham Mine, 9 contained copper in excess of 1 percent, with a high value of 4.2 percent in a 28 inch chip sample. The highest uranium content was 48 ppm in a grab sample taken on a 4-foot grid. Barite was found as small white pods in one adit and in several pits. The highest barium content was 6.1 percent (Lane, in press).

Grand Gulch Mine

The Grand Gulch Mine is about 1/4 mile from the Pigeon Canyon WSA in the SE 1/4 of section 21, and SW 1/4 of section 22, T. 34 N., R. 14, W. (plate 1 and fig. 2).

Copper was first discovered in June 1853 by Richard Bentley, Samuel S. Adams, and others. The prospect was said to have been bought by Mr. Adams from the Indians (presumably the Paiute) for a horse and some flour. The Grand Gulch was the first mine within the Bentley Mining District. The Bentley Mines were recorded in Mohave County, Arizona (Kingman), on June 23, 1873, by Richard Bentley (Billingsley, unpublished manuscript).

In 1870, an adobe smelter was built at the Grand Gulch Mine, but never successfully operated. The prospect was acquired in 1890 by the Jennings brothers, who worked the mine intermittently for 16 years. Thomas W. Jennings named the prospect "The Grand Gulch Mine." From 1901 to 1958, the mine has produced copper ore sporadically; by 1951 production totalled 15,701 tons of ore, containing 24,349 oz silver, 6,651,610 lb copper, and 715 lb lead (Lane, in press).

By 1913 a shaft was sunk to about 500 feet below the surface in the center of a generally circular, pear-shaped ore body--a collapse structure. The ore body is in rocks of the Pakoon Limestone and is vertically limited to an interval of less than 250 feet (Hill, 1915).

Mineralization occurs mostly along the pipe periphery. Hill (1915) reported that the ore bodies are lens-like or form irregular pods and are composed of malachite, azurite, brochantite, and chalcocite. Baillicul and Zollinger (1980) state that the degree of brecciation decreases and finally dies out at about 230 feet below the surface. The lower levels of the mine were not accessible during the present investigation. Consequently, it is not known whether the Grand Gulch has been mined out. A few of the samples collected represent ore-grade material. These samples sites are so erratically distributed that calculation of reserves is not practical. However, the breccia pipe at the Grand Gulch Mine may still contain copper resources.

The highest copper content found at the Grand Gulch Mine was 12.2 percent in a 36-inch chip sample, the highest silver was 2.4 ounces in a 36-inch chip sample, and the highest U_3O_8 content was 13 ppm in a 24-inch chip sample (Lane, in press).

Prospects in Snap Canyon

A trench and two short adits in upper Snap Canyon in the NW 1/4 of section 13, T. 32 N., R. 14 W., were the only diggings found within the Snap Canyon WSA. No visible mineralization was present. The trench was completely in alluvium; the adits were in alluvium at the portals and ended in what appeared to be fractured and altered Hermit Shale. One adit ended in saprolite and may have been developed to collect spring water (Lane, in press).

MINERAL RESOURCE POTENTIAL

General statement

New discoveries of uranium ore on the Colorado Plateau have rekindled interest in reactivating the old copper mines for uranium ore. Recent and current studies of ore deposits on the Colorado Plateau have shown that many copper and uranium deposits are associated with collapse structures, but there is no agreement on how this mineralization occurred (Bowles, 1965 and 1977; Hoffman, 1977, Lovejoy, 1954, Watkins, 1976, and Wenrich and Sutphin, 1983). The greatest likelihood for mineral occurences in the WSAs is in these mineralized collapse structures. Even though most collapses are not mineralized, those that are have yielded substantial quantities of uranium, copper, and other metals (Hill, 1915, Lovejoy, 1954, and Gornitz, 1970). Because of this and because the collapse structures in the area are close to known mineralized mines, all collapse structures within the WSAs are considered to have at least a moderate mineral potential.

The mines in the study areas are all located on collapse structures developed in limestone, shale and sandstone of the Pakoon and Callville Limestones of Permian age. Collapse structures other than those at the mines were unknown before this study. Four new collapse structures have now been found, all in the Pigeon Canyon WSA. These structures are not mineralized at the surface and no prospecting has been done on them. However, large blocks of land in nearby areas, including one of the collapse structures, have been staked and claimed recently, presumably for uranium. Several studies (including geologic maps) at least partially concerned with collapse structures have been made just east of the WSAs (Hoffman, 1977; Huntoon, 1981 and 1982; Billingsley and Huntoon, 1983; Billingsley, Antweiler, and Ellis, in press; and Wenrich, K. J., written communication).

Within the collapse structures, areas that are most favorable for mineralization are restricted to the outermost part of the structures, where rock strata begin to dip towards the central area of the collapse. Collapse structures are known to bottom out in the Redwall Limestone of Mississippian age (Sutphin and others, 1983). Because of this, collapse structures in all areas covered by this report have a depth for potential mineralization not exceeding 800 to 900 feet.

Pigeon Canyon WSA

At the collapse structure near the Savanic Mine the mineral resource potential for uranium and base and precious metals is high. The Savanic Mine is partly outside the WSA, about 100 yards west of the associated collapse structure which is within the Pigeon Canyon WSA; mineralization at the mine occurs on joints in the Callville Limestone (Wescogame Formation of McKee, 1982). Four other collapse structures within the area (fig. 2) have a moderate mineral resource potential for the reasons that have been stated. The remainder of the Pigeon Canyon WSA has a low mineral resource potential for metals.

Silty gypsum deposits that occur in the Muddy Creek Formation in the western half of the WSA have a low mineral resource potential for gypsum and associated minerals. Many other gypsum deposits occur in southern Utah and northern Arizona that are more readily accessible. The slightly anomalous amounts of uranium and molybdenum associated with the gypsum represent no more than a low potential at best for those commodities in this area.

The oil and gas potential of the part of the WSA west of the Grand Wash fault has been assessed by Ryder (1983) as medium (equivalent to "moderate" of this report); he rates the area east of the fault as having a low potential for hydrocarbons. West of the fault Paleozoic reservoir rocks are buried; to the east they are visibly faulted, exposed, and more susceptible to freshwater flushing.

Nevershine Mesa WSA

The Nevershine Mesa WSA has an overall low mineral resource potential for uranium and base and precious metals. However, a high resource potential exists at the Cunningham Mine, partially within the WSA (fig. 2). The Cunningham Mine is within a large collapse structure with visible breccia and copper and iron minerals at the surface.

The boundary between the Pigeon Canyon and the Nevershine Mesa WSAs follows a road that cuts through the Savanic Mine. The Savanic collapse structure is within the Pigeon Canyon WSA. However, the nearby part of the Nevershine Mesa WSA has a moderate mineral resource potential for metals because it lies between two known mineralized collapse structures only 3/4 mile apart, and because it may contain mineralized joints similar to those at the Savanic Mine.

Nonmetallic mineral resources are abundant in all the WSAs; they include building stone, sand and gravel, gypsum, and limestone. Because of their inaccessibility and distance from market, no attempt was made to estimate the identified resources.

Ryder (1983) also rates the oil and gas potential of the Nevershine Mesa WSA as medium ("moderate") west of the Grand Wash fault and low east of the fault, for the reasons noted for the Pigeon Canyon WSA.

Snap Point WSA

The Snap Point WSA has a low mineral resource potential for metals. No collapse structures were found. The one small known prospect in the area presumably was dug to develop a spring (Cox and Russell, 1973; Lane, in press). Ryder (1983) rates the oil and gas potential as low, as the WSA lies entirely east of the Grand Wash fault.

Resource classification

The resource potential for copper, uranium, silver, lead, zinc, other metals, and barite is moderate or high in the known collapse structures (which include the three mines). Medium- to low-grade copper and other metal resources may exist at the known prospects and mines of the Pigeon Canyon and Nevershine Mesa WSAs. The likelihood of the occurrence of additional localized collapse structures in the WSAs is low; accordingly the mineral resource potential for the rest of the area of the WSAs is low. No known mineralized prospects are present in the Snap Point WSA.

The resource potential for gypsum is considered low for the reasons discussed earlier in this report. Building stone, sand and gravel, and limestone deposits are numerous; the materials are not considered economic because they are readily available outside the study area where they are closer to markets in Utah and Nevada. The Paleozoic rocks have a moderate potential for oil and gas west of the Grand Wash fault in the Pigeon Canyon and Nevershine Mesa WSAs where the Paleozoic rocks have been downfaulted and covered by Tertiary sediments. Although available data is sparse, these areas are the most favorable for oil and gas. Most of the Paleozoic rocks are exposed along the Grand Wash Cliffs east of the fault, and oil and gas may have been susceptible to freshwater flushing (Ryder, 1983). East of the fault in all three WSAs, the resource potential for oil and gas is low.

Coal-bearing units were not observed in the exposed Paleozoic rocks and are not known to exist in the subsurface of the three wilderness study areas.

Conclusions

Geologic mapping and a mineral survey undertaken in 1981-1983 suggest that the Pigeon Canyon and Nevershine Mesa WSAs offer some promise for the occurrence of mineral resources, but only in very localized collapse structures. These resources are likely to be uranium and (or) copper, and their tonnage is likely to be limited. Little or no promise for occurrence of mineral resources exists in the Snap Point WSA. The WSAs have a moderate resource potential for oil and gas west of the Grand Wash fault, a low potential east of it. Gypsum, sand and gravel, and building stone are abundant in all three WSAs but adequate supplies of these materials are available closer to markets.

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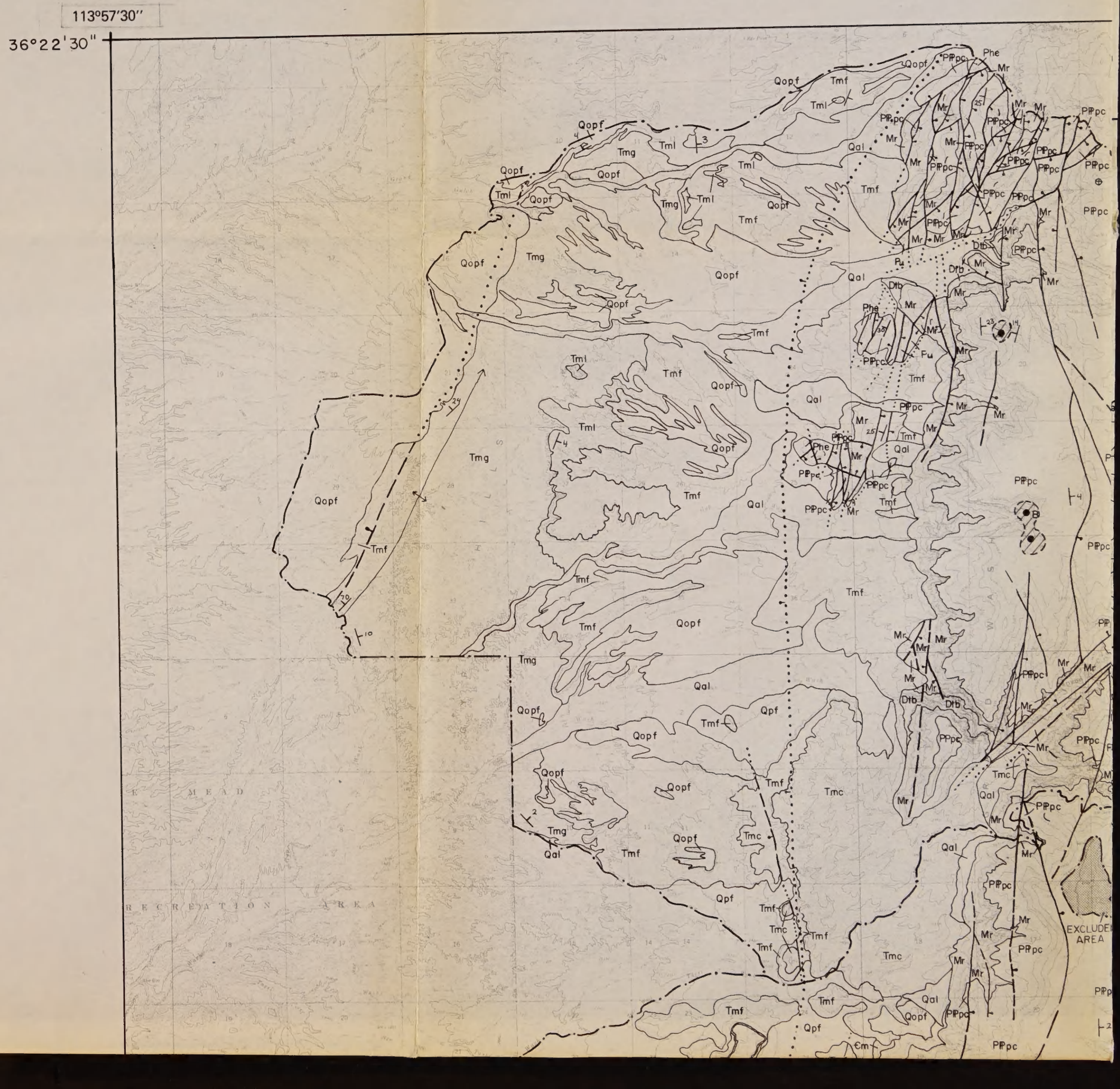

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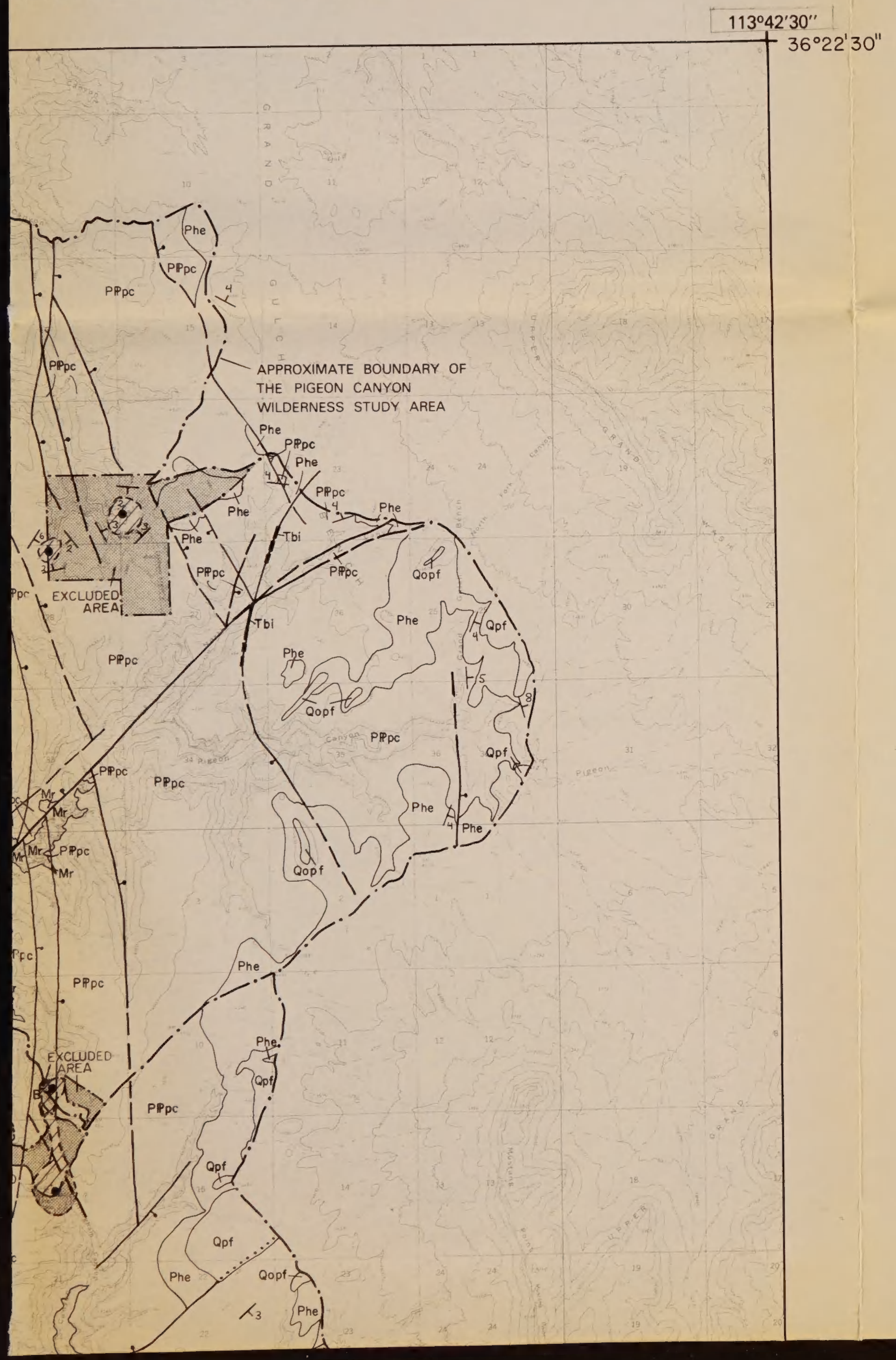

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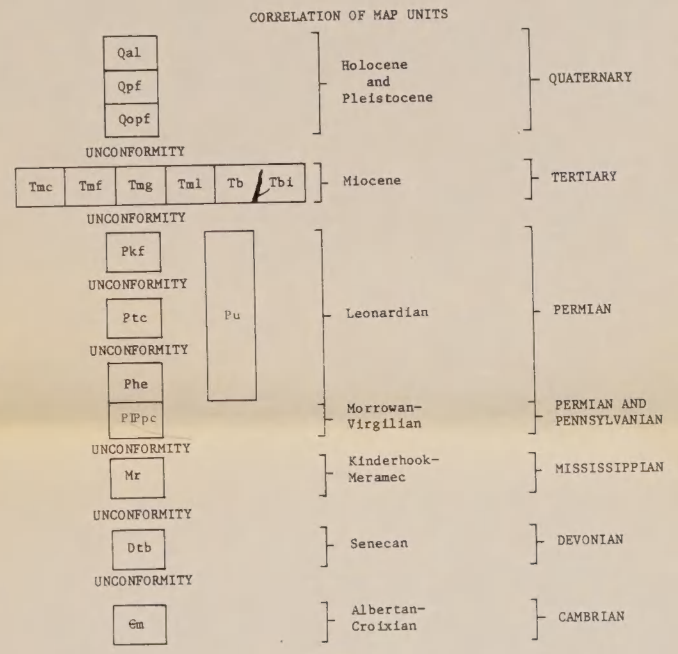
PLATE 1 OF 1
PAMPHLET ACCOMPANIES MAP

CORRELATION OF MAP UNITS



DESCRIPTION OF ROCK UNITS

Qal RECENT ALLUVIUM (QUATERNARY)--Unconsolidated, poorly sorted, angular boulders, cobbles, gravel, sand, silt, and clay within currently active washes. Inset into other deposits, including other Quaternary units. Tan to light gray. Little or no vegetation cover. Thickness unknown, but probably a few feet at most

Qpf PEDIMENT AND FAN GRAVELS (PLEISTOCENE TO RECENT)--Unconsolidated to poorly consolidated, poorly sorted gravel deposits of pediments and alluvial fans. Composed of angular to subrounded clasts of local derivation, ranging in size from boulders to sand. Typically form relatively smooth surfaces. Thickness unknown but probably a few tens of feet at most

Qopf OLDER PEDIMENT AND FAN GRAVELS (PLEISTOCENE)--Erosional remnants of poorly to well consolidated, poorly sorted pediment and fan gravels of various ages. Lithologically similar to Qpf, but dissected and exposed as isolated remnants topographically higher than nearby Qpf. In places, strongly cemented into calcrete. Thickness typically less than 50 feet

MUDDY CREEK FORMATION (MIOCENE)

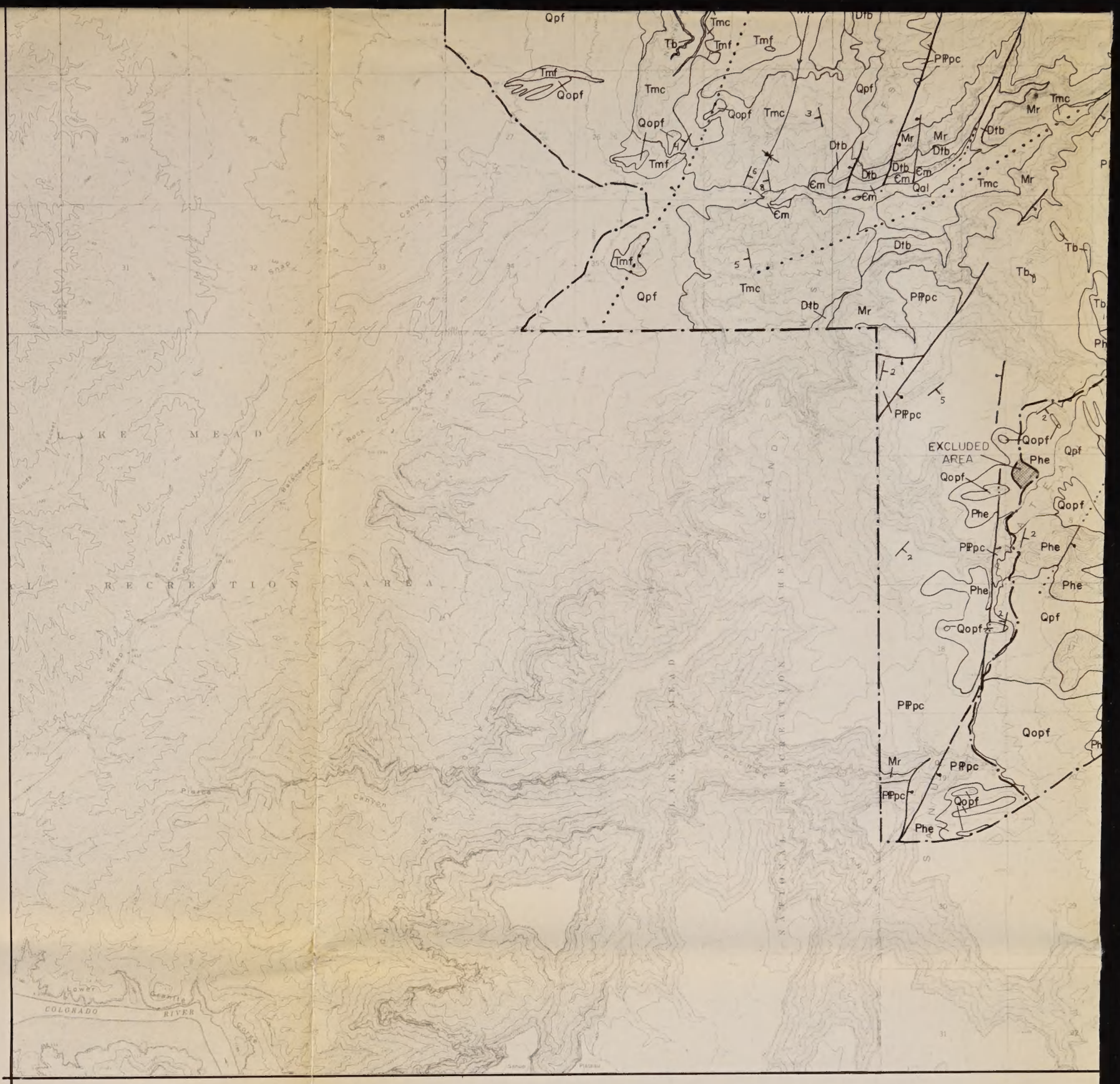
Poorly consolidated to well consolidated, poorly bedded to well bedded conglomerate, sandstone, siltstone, mudstone, claystone, fresh-water limestone, and gypsum. Thin tuff beds present in places. In general, fine-grained facies occur in the upper part of the sequence and the central part of the basin. Facies generally grade into each other through intertonguing and lateral gradation; there is no constant order of superposition (Luchitta, 1966). Map contacts between facies approximate, placed arbitrarily at change in dominant lithology. Colors: conglomerate--pinkish tan to light gray; sandstone, siltstone, and shale--pinkish tan to brick red; limestone and gypsum--off-white, light pinkish gray, pinkish gray. Thickness: unknown, probably several thousand feet

Tmc	Conglomerate facies
Tmf	Sandstone-siltstone-mudstone facies
Tmg	Gypsum facies
Tml	Limestone facies

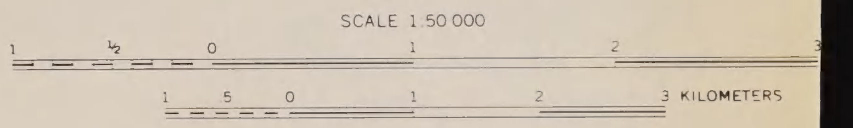
Tb OLIVINE BASALT (MIOCENE)--Sparsely porphyritic, nearly unweathered basalt, vesicular to scoriaceous in places. Typically contains 5-10 percent iddingsitized olivine as much as 5 mm but typically about 1 mm in size, brown plagioclase common. Equigranular matrix, felty texture locally. Thickness: 0 to 250 ft. Has yielded a K/Ar age of "about 9.2 m.y." (J. F. Haman, written communication to G. E. Ulrich, 1983). "Tbi" denotes olivine basalt dike

Pkf FOSSIL MOUNTAIN MEMBER OF KAIBAB FORMATION (LEONARDIAN)--Cliff-forming, thickly bedded, gray to light tan-gray fossiliferous limestone, granular to finely crystalline, containing networks of granular gray chert veinlets in the lower portion and dark gray to brown concretionary chert in the upper portion. Forms highest of two massive cliffs near top of Paleozoic rock sequence. Thickness 300 to 350 ft

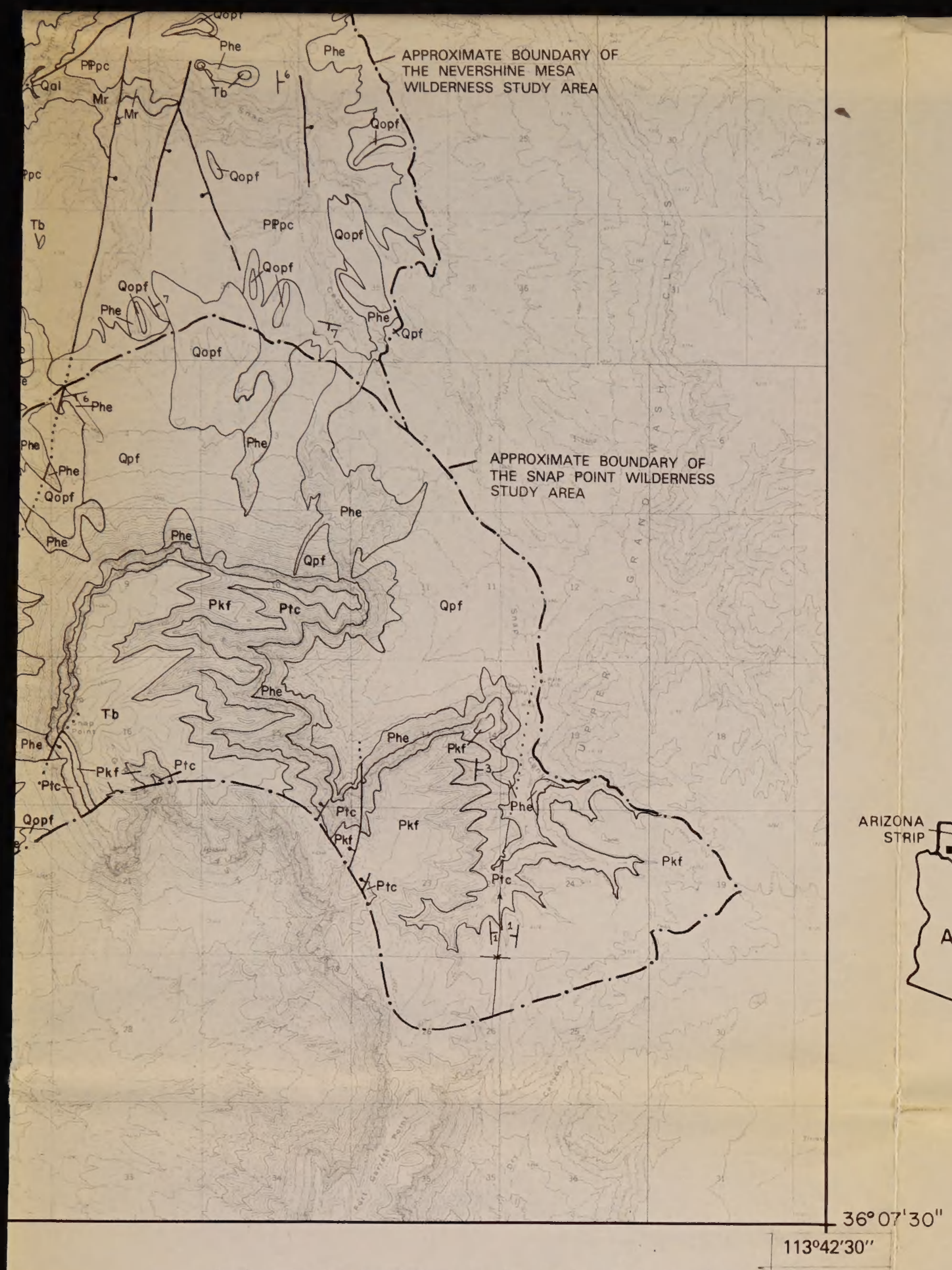
Ptc TOROWEAP FORMATION AND COCONINO SANDSTONE UNDIVIDED (LEONARDIAN)--Consists of three units; two relatively thin, red to yellow-brown, highly gypsiferous, friable, slope-forming sandstone separated by a conspicuous, massively bedded, coarsely crystalline limestone that forms the largest single cliff in the



Base from U.S. Geological Survey 1:24,000 quadrangles, Grand Gulch Bench (1971), Gyp Hills (1971), Mustang Point (1971), Snap Canyon East (1971), Snap Canyon West (1971), and Snap Draw (1971)



GEOLOGIC AND MINERAL POTENTIAL MAP OF THE PIGEON CANYON (AZ-010-109), NEVER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Geology by Ivo Lucchitta, L. S. Beard, and H. J. Rieck, 1981-83, with modifications from Huntoon, Billingsley, and Clark (1982) for part of the Snap Point Wilderness Study Area

upper Grand Wash Cliffs in the Snap Point WSA. The Coconino Sandstone, a buff to reddish-white, fine-grained quartz sandstone displaying large-scale high-angle cross beds is included within the Toroweap unit because it is less than 60 ft thick and locally absent in this area. Thickness 350-450 ft

Phe HERMIT AND ESPLANADE FORMATIONS UNDIVIDED (HERMIT: LEONARDIAN; ESPLANADE: WOLFCAMPIAN)--Thinly bedded, brick-red siltstone and deep-red shaly siltstone (Hermit), overlying light-red to white, medium-to thick-bedded, fine-grained, cross-laminated, locally silty sandstone with thin- to medium-bedded, gray to tan dolomitic limestone layers and minor, local, limestone-pebble intraformational conglomerate in the lower part (Esplanade Formation of Supai Group). Contact between Hermit and Esplanade appears interfingering and transitional, but throughout the western Grand Canyon area is marked by an obscure unconformity, difficult to recognize and of low relief (McKee and Crosby, 1975 p. 305-308; McKee, 1975; Billingsley, 1978, p. 12-13). Weathers to slope broken near base by several small cliffs. Thickness about 1,200 ft. Along the Grand Wash Cliffs, the lower part of the Esplanade Sandstone includes the correlative Pakoon Limestone of McNair (1951), mapped here together with the underlying Callville Limestone

Pu PERMIAN ROCKS, UNDIVIDED (LEONARDIAN THROUGH WOLFCAMPIAN)--Includes Kaibab Formation, Toroweap Formation, Hermit Formation, and Esplanade Formation. Occurs in highly faulted blocks in which it is impractical to map individual formations

PIPpc PAKOON LIMESTONE (WOLFCAMPIAN) AND CALLVILLE LIMESTONE (MORROWAN-VIRGILIAN) UNDIVIDED--Pink-gray to gray, fine-grained, medium-bedded fossiliferous, locally cherty dolomitic limestone forming ledge-slope (Pakoon), overlying gray to pink-gray, fine- to coarse-grained, locally oolitic, locally cherty, and cross-bedded, cliff-forming limestone and sandy limestone interbedded with slope-forming reddish-weathering shaly limestone and calcareous shale, and cliff-forming, commonly cross-stratified sandy limestone to calcareous sandstone (Callville). Thicknesses: Pakoon - about 300 ft, Callville - about 700 ft, total about 1,000 ft for the map unit

Mr REDWALL LIMESTONE (KINDERHOOK TO MERAMEC)--Light-gray, aphanitic to sugary, thin- to thick-bedded, fossiliferous, in part cherty limestone forming a massive cliff. Thickness 650 to 700 ft

Dtb TEMPLE BUTTE FORMATION (SENECAN)--Gray to olive-gray, medium-grained, typically fetid limestone in medium to thick beds. More resistant and less resistant beds alternate, producing a steep ledge-slope. Thickness about 450 ft

Ꞓm MUAV LIMESTONE (ALBERTAN AND CROIXIAN)--Gray, very fine grained, thin-bedded dolomitic limestone, and whitish, sugary, laminated dolomite ("undifferentiated dolomite" of Billingsley, 1978, p. 5). Forms massive cliffs separated by steep slopes. Thickness about 650 ft

EXPLANATION OF MAP SYMBOLS

CONTACT

FAULT--Dashed where approximately located; dotted where concealed. Bar and ball on downthrown side

ANTICLINE--Showing direction of plunge

SYNCLINE--Showing direction of plunge

STRIKE AND DIP OF BEDS

⊕ HORIZONTAL BEDS

APPROXIMATE BOUNDARY OF STUDY AREA

COLLAPSE STRUCTURE -- B indicates exposed breccia. Dashed line denotes boundary of potentially mineralized area

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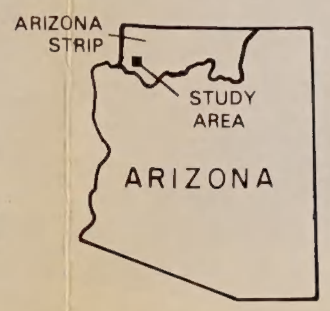

RSHINE MESA (AZ-010-105A), AND SNAP POINT (AZ-010-105B) WILDERNESS STUDY AREAS, MOHAVE COUNTY, ARIZONA

This map is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.